



VOLUME 78

SEPARATE No. 154

# PROCEEDINGS

AMERICAN SOCIETY  
OF  
CIVIL ENGINEERS

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A NAVIGATION CHANNEL TO  
VICTORIA, TEX.

By Albert B. Davis, Jr.

WATERWAYS DIVISION

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Printed in the United States of America*

**Headquarters of the Society**  
33 W. 39th St.  
New York 18, N.Y.

PRICE \$0.50 PER COPY

2620.6  
A 512p

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AMERICAN SOCIETY OF CIVIL ENGINEERS

Founded November 5, 1852

PAPERS

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A NAVIGATION CHANNEL TO VICTORIA, TEX.

BY ALBERT B. DAVIS, JR.<sup>1</sup>

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SYNOPSIS

The navigation channel to Victoria, Tex., will provide a channel for barge transportation as a feeder or tributary channel to the Gulf Intracoastal Waterway. The engineering problems involved are those of location and design of the channel and appurtenant facilities. Separate plans are presented for a sea-level canal and for a lock canal. Comparison of the two plans on a cost basis favors the sea-level plan and, because of the inadequate water supply for operation of a lock canal, it is concluded that the sea-level canal is preferable for a navigation channel to Victoria. The conclusions presented in this paper are those of the writer and do not necessarily represent the views of the Corps of Engineers, United States Department of the Army.

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INTRODUCTION

The federal Guadalupe River Project for a navigation channel to Victoria is an example of the tributary or feeder channels of the Gulf Intracoastal Waterway on the Texas Gulf Coast. These feeder channels extend inland about as far as it is practicable to carry a tide-water or sea-level canal. The problems that are encountered in locating and designing the channel to Victoria were generally similar to the problems encountered on the initial extension of navigation upstream from the coastal waters.

The Guadalupe River, one of the larger streams in Texas, has a drainage area of about 10,200 sq miles, including the San Antonio River, its principal tributary, which empties into the Guadalupe River 11 miles above its mouth and has a drainage area of about 4,200 sq miles. The drainage area of the Guadalupe, exclusive of the San Antonio River, is about 6,000 sq miles. The Guadalupe River empties through Mission Lake and Guadalupe Bay into San Antonio Bay (one of the larger coastal bays on the Texas coast) which is separated from the Gulf of Mexico by Matagorda Island, an off-shore bar formation.

NOTE.—Written comments are invited for publication; the last discussion should be submitted by April 1, 1953.

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Connection between San Antonio Bay and the Gulf of Mexico is indirect through several small bays to a permanent pass on the north and an intermittent pass on the south. The main channel of the Gulf Intracoastal Waterway extends along the mainland shore of the small coastal bays and across the lower end of San Antonio Bay. The vicinity of the project channel is shown in Fig. 1.

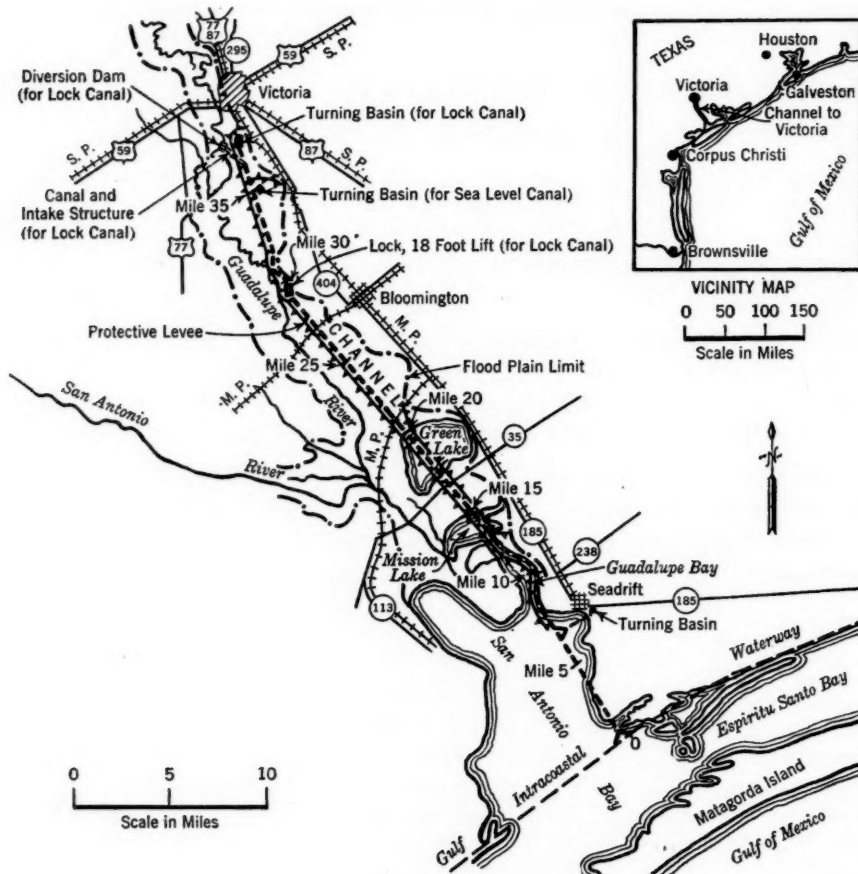


FIG. 1.—CHANNEL TO VICTORIA, TEX.

The City of Victoria is on the left bank of the Guadalupe River, 52 miles above its mouth and about 40 miles on an air line from the Gulf Intracoastal Waterway at the lower end of San Antonio Bay. The town of Seadrift, Tex., lies on the northeast shore of San Antonio Bay about 7 miles from the Intracoastal Waterway and about 5 miles from the mouth of the Guadalupe River.

The valley of the Guadalupe River below Victoria is well defined by bordering bluffs. The elevation of the general land surface slopes at a uniform rate about 65 ft above mean sea level in the vicinity of Victoria to 25 ft at the mouth

of the river, 10 ft in the vicinity of Seadrift, and 1 ft or 2 ft adjacent to the Intracoastal Waterway. The river valley is entrenched in this land surface, and has surface elevations of about 55 ft at Victoria and 1 ft or 2 ft near the mouth of the river. The river channel meanders through the valley with bed elevations of 30 ft at Victoria, decreasing to - 18 ft just above the delta at River Mile 4, rising to - 10 ft at the mouth and 1 ft on the bar at its mouth in Guadalupe Bay. The river is tidal for about 25 miles above the mouth. The height of the river banks varies from 20 ft to 25 ft at Victoria to from 3 ft to 5 ft at the mouth, and the width of the stream channel varies from 100 ft to 175 ft. Natural depths of about 4 ft at mean sea level are available over most of San Antonio Bay, and from 1 ft to 3 ft in Guadalupe Bay and Mission Bay.

The river valley is entrenched in the geological formation known as Beaumont clay, which consists of thick clay strata interbedded with sand strata and sand lenses. The valley is composed of recent deposits of Beaumont clay and deposits from upland erosion. In the vicinity of Victoria, the valley floor is underlain by extensive deposits of sand and gravel of commercial value. Sand and gravel deposits in pockets and lenses are found throughout the valley below Victoria.

#### HISTORY

Navigation has long been considered desirable on the Guadalupe River. In fact, surveys to determine the possibilities of improvements for navigation were made as early as 1875. However, it was considered impracticable to improve the river at that time. Further surveys were made during the following years and in 1907 a federal project for improvement of the river was adopted, which provided for a channel 5 ft deep, 40 ft wide, and 16 miles long across San Antonio Bay to the mouth of the Guadalupe River. The project also required the removal of snags and log rafts and the dredging of shoals to provide a navigable channel in the river with a depth of 5 ft at ordinary low water from the mouth of the river to Victoria, a distance of 52 miles. Under this project considerable work was completed; however, it was found that removal of the log rafts and other obstructions had lowered the water level at Victoria to such an extent that a depth of only 3 ft could be obtained by open channel work. Investigations in 1915 indicated that it would not be feasible to canalize the river with locks and dams and that there was not sufficient commerce to justify the expenditure of funds under the existing project. The project was not abandoned by Congress, but no work was done after 1916, and the river channel soon returned to its natural condition.

A comprehensive report on the possibilities of navigation on the Guadalupe River was made in 1935 and a plan for improvement of the river to Victoria was proposed which provided for three low-lift locks and dams in the natural river channel. It was found, however, that the probable benefits to commerce would not be sufficient to justify the improvement at that time.

The next investigation of the river for navigation purposes was made in 1938. The report on that investigation favored improvement for navigation and resulted in the existing project which was authorized by Congress in the River and Harbor Act of March 2, 1945, in accordance with the reports printed in *House Document No. 247*, 76th Congress, 1st session.

## PROJECT PLAN

The plan recommended in the project document report (*House Document No. 247*, 76th Congress, 1st session) for improvement of the Guadalupe River provides for a channel 9 ft deep and 100 ft wide, extending from the Gulf Intracoastal Waterway, by way of Seadrift, to a point on the Guadalupe River 3 miles above Victoria. The channel dimensions were selected to conform to those of the main channel of the Intracoastal Waterway, which, at that time, were 9 ft deep at mean low tide by 100 ft wide on bottom. (Mean low tide datum used by the Corps of Engineers is 1 ft below mean sea level.) The authorized plan provides for a lateral canal with two navigation locks having a total lift of 36 ft. It was proposed to install hydropower generating units at each of the locks and to protect the channel and adjacent land from floods by constructing a protection levee along the river side of the channel. Subsequently, in a favorable report, construction of a harbor of refuge at Seadrift was recommended as a part of the project for a channel to Victoria.

The recommended plan was authorized subject to the provisions that local interests: (1) Furnish all lands, easements, rights of way, and spoil disposal areas; (2) hold the United States free from claims for damages from construction and maintenance of the project; (3) bear all costs of required bridge modification; and (4) provide adequate terminal facilities including turning basins at Seadrift and Victoria.

The studies made during the course of the investigations that led to recommendation of the project were to determine the most feasible route for a navigable channel to Victoria and to develop the adequacy of the water resources of the river for the operation of the proposed navigation locks and power plants. The investigation also developed the costs and benefits of the proposed channel to show its economic measure and the advisability of federal construction of the navigation improvement.

The authorized project provides for the location of the channel inshore along the bay section and as a lateral canal in the river section. The inshore location from the Intracoastal Waterway to the mouth of the Guadalupe River follows the practice of the Galveston District, Corps of Engineers, of locating shallow-draft channels inshore rather than in the open waters of the shallow coastal bays, whenever feasible, in order to reduce the maintenance cost. The lower maintenance cost of inshore locations has been amply demonstrated in the experience of the Galveston District. Above the mouth of the river, the route lies in the left flood plain of the river, following generally the channels of several sloughs that meander down the flood plain. The channel enters the river immediately downstream from Victoria at the proposed site of the Victoria turning basin. The lateral channel route was selected instead of a natural river channel route because it would:

- a. Avoid the deleterious effects of frequent flooding in the lower valley and the consequent interruptions to traffic;
- b. Be about 9 miles shorter;
- c. Require one less lock and two less dams;
- d. Involve a substantially lower first cost;

- e. Require materially smaller costs for maintenance and operation;
- f. Afford flood protection to a considerable area of the natural flood plain; and
- g. Provide opportunity to drain considerable area of poorly drained land in the protected area.

Water supply studies made during the investigations indicated an ample supply for operating the locks and for generating sufficient electric power to justify the installation of hydroelectric generators at the two dams. The minimum flow of record is 150 cu ft per sec.

Following authorization of the present project in 1945, funds were made available for detailed planning of the improvement. Field surveys were made to furnish a topographic map with a 1-ft contour interval of a 2,000-ft strip along the route of the lateral navigation canal. At the same time, borings were made along the route of the canal to obtain knowledge about the subsurface materials.

In the interval following the project report, development of a rice irrigation system and location of an industrial plant on the lower Guadalupe River, both dependent on the river flow for water supply, were started. The appropriation of water for these activities raised the question of the adequacy of the water resources for operation of a lock canal. Accordingly, it was decided to include consideration of a sea-level canal in the detailed planning studies.

The planning studies covered the determination of the following:

1. The most feasible alinement for a lock canal and a sea-level canal from the standpoint of cost and navigation requirements;
2. Details of the appurtenant features of a lock canal and of a sea-level canal;
3. The adequacy of the water resources of the region to supply agricultural, industrial, and navigation demands; and
4. The most feasible plan for a navigation channel to Victoria.

#### CHANNEL ALINEMENT

At the beginning of the planning studies to determine the channel location and alinement, reconsideration was given to a lateral canal as compared to a canal in the natural river channel. This study showed that the advantages of the lateral canal in lowering first cost and maintenance cost and in affording a more dependable and safer channel for navigation were sufficient to discard any further consideration of improving the natural river channel to provide navigation to Victoria. Consideration also was given to the feasibility of locating a lock in the vicinity of Guadalupe Bay and locating the canal on the high bordering bluff from that point to Victoria. This location avoided some of the difficulties encountered in placing the channel in the flood plain, but the considerably higher cost of rights of way and the high severance damages involved made this location impracticable and it was not studied further. The most feasible location for the lateral navigation channel is in the left flood plain. The alinement of the channel is the same for either a lock canal or a sea-level canal.

Locating the channel route along the northeast side of San Antonio and Guadalupe bays, and Mission Lake, offered no particular difficulty, although several different alinements were studied. The selected route is on a straight line from the junction with the Intracoastal Waterway to the upper end of San Antonio Bay. This route avoids severing very much property in crossing the point of land between miles 1.4 and 3.6. From mile 3.6 to mile 8.7, the channel crosses the open side of the embayment on which Seadrift is located. A branch channel extends from mile 7 to a commercial turning basin at the town of Seadrift. The Seadrift basin is to be designed and constructed by the local interests.

From mile 8.7 to mile 13.6, the channel is located along the bay shore line adjacent to the foot of the bluff bordering Guadalupe Bay. This location affords the adjacent high land ready access to the channel for navigation; it avoids the excessive volume of excavation that would be entailed in cutting through the bluff which reaches an elevation of about 20 ft; and it permits the construction of a spoil-bank levee along the bay side of the channel to protect navigation on the channel.

Continuing above mile 13.6, the location was determined by the crossing of Green Lake. The bed of this lake is privately owned. The owners have studied the possibility of developing Green Lake and are considering several diverse plans. One would be to pump the lake dry so that the bed could be used for agricultural land, and another plan would be to use the lake as a storage reservoir to supply water for irrigation of agricultural land on the high ground. The navigation canal could not be coordinated functionally with any of these plans and must be separated completely from Green Lake. Locations were considered between Green Lake and the Guadalupe River and along the east shore of the lake. The former location was discarded because the protection levee would constrict excessively the flood plain of the river and result in increased flood heights in the flood plains of the San Antonio River and the Guadalupe River above Green Lake. The river lies along the right side of the flood plain in the vicinity of Green Lake and locating the channel with its river side levee between the river and the lake would reduce the flood plain width from 20,000 ft to 6,000 ft which would seriously increase flood heights. A location along the east shore of Green Lake would require an excessive degree of curvature in the channel. Accordingly, it was decided to locate the channel across the middle of the lake. This location permits a practically straight alinement from mile 12 to mile 30.

Above Green Lake, locating the channel along the course of a bayou running through the reach from the lake to mile 30, as proposed in the project report was considered; however, there was little reduction in the quantity of excavation on this alinement and a number of curves were also introduced. The straight alinement is preferable. The first lock in the lock canal would be located at mile 29.6 and would provide a lift of 18 ft, raising the water surface above the lock to an elevation of 18 ft above mean sea level.

From mile 30 to mile 32.5, the river channel lies close to the edge of the flood plain which is against a steep hillside in this reach, and the channel and levee must be located between the toe of the slope of the bluff and the river

channel. Several spur hills, about 20 ft in height above the general elevation, must be cut by the channel. At four points in this reach, the center line of the channel is within 800 ft of the center of the river channel.

Above mile 32.5, the channel follows a generally straight alinement located so that it would not constrict the flood plain width to less than the width at valley control points. No particular alinement problems are encountered in this reach, which extends to the proposed turning basin.

Suitable sites for the turning basin are available at mile 38 and mile 35. The site at mile 38 is a wide, level area that would permit port development at an elevation of 47 ft above the water surface in a sea-level canal and about 29 ft above the water surface of a lock canal. The maximum cut for a lock canal would be about 40 ft. The site at mile 35 has an average elevation of about 30 ft and would permit port development at an elevation of 30 ft above the water surface of a sea-level canal and about 12 ft above the water surface of a lock canal. The maximum cut for a sea-level canal would be 41 ft. Both sites afford readily available access to railroad service through spur connections that could be extended to the turning basin areas with equal facilities for either site.

The location of the turning basin at these sites differs from the location given in the project document plan, which shows the turning basin further upstream above a second lock. Either of the two downstream locations would reduce the costs of the channel by eliminating one lock structure and would serve the commercial tributary areas satisfactorily.

#### CHANNEL AND LEVEE SIDE SLOPES

Investigation of the subsurface soils was made to determine the character of materials to be excavated; to determine the side slopes of the channel and the protection levee; to determine the foundation conditions for structures and levees; and to determine the possible seepage from the canal. A total of 147 holes were drilled in these explorations, of which 122 holes were on the final channel alinement. Of these holes 107 were earth auger holes and 15 were cored holes. The holes were spaced about a half mile apart.

The investigations reveal that the subsurface materials encountered on the channel alinement are principally sands and sandy clays in the reach from the Intracoastal Waterway to about mile 15, and clays and sandy clays in the part of the canal above mile 15. A number of gravel deposits occur in the reaches above mile 25.

The design of the canal slopes was based on estimates of the shearing strength of the principal types of material found in typical borings. The estimates were based on the general characteristics of the soils, and on a knowledge of the behavior of soils with these characteristics. The values of these estimated shearing strengths were checked by shear tests on samples of the weakest materials. From these strength values and the thickness of strata, weighted values for the cohesion strength  $c$  and friction angle  $\phi$  were determined for the materials at each hole. From these values and the depth of cut, the slopes were determined by the  $\phi$ -circle method. A safety factor of 1.3 was considered sufficient. The water level in the canal will be nearly constant and there

should be no rapid drawdown of the water surface sufficient to weaken the stability of the canal slopes.

The levee slopes were determined in a similar manner. The value of  $c$  for hydraulic fill was assumed to be 75% of the value of  $c$  for material in the borings. The value of  $\phi$  for the angle of friction was assumed to be 25% of

TABLE 1.—ESTIMATED SIDE SLOPES FOR CANAL AND LEVEE

Reach (miles)	Canal	LEVEE FILL	
		Dragline	Hydraulic
0 to 10.0	1 on 5	None	None
10.0 to 20.3	1 on 3	None	1 on 6
20.3 to 32	1 on 2	1 on 2	1 on 4
32.2 to 38	1 on 2	1 on 2	1 on 4

the value of  $\phi$  for the material in the adjacent boring. A factor of safety of 1.3 was used also in deriving the levee slopes. These slopes were determined at each boring location. The slopes for a levee of dragline fill were considered to be the same as the canal slopes.

For the purposes of estimating quantities and costs the slopes of the levee and canal as determined at each boring location were then tabulated and divided into reaches of similar slopes. A constant slope for each reach was selected which was as steep as most of the individual slopes. The slopes so determined are shown in Table 1.

#### LEVEE GRADE

The levee along the river side of the canal would afford protection to the canal and the area between the canal and the edge of the flood plain from floods on the Guadalupe River and the San Antonio River. The levee grade above mile 12 was determined from the flood height of the maximum flood of record as increased by the backwater effect of the proposed levee. The maximum flood of record occurred on July 3, 1936, and reached an elevation of 60.45 ft above mean sea level at Victoria. The peak discharge was 179,000 cu ft per sec. Backwater computations indicate that the constriction of the flood plain caused by the protection levee would increase the height of a flood of this magnitude by about 3 ft. Accordingly, the levee grade was set at about 6 ft above the high-water profile of the flood of July, 1936, which provides a free-board of about 3 ft for the recurrence of the maximum storm of record. Profiles of the high water for the maximum flood of record and for the levee grade are shown in Fig. 2. The average levee grade is at a height of about 13 ft above the average ground surface. Actually this levee grade will be used only in the reach from mile 12 to mile 22 where levees are provided on both sides of the channel. In all other areas the quantity of excavated material will exceed the quantity of material required to construct the levee to the design grade.

Below mile 12 the riverside levee serves to reduce the maintenance of the channel and to contain the salt water in the navigation channel and prevent contamination of the fresh water supplies in the adjacent bodies of water which are used for irrigation. The levee grade is set at 6 ft in this reach. A parallel levee is required on the land side of the channel from high ground at about mile 12 below Mission Lake to high ground above Green Lake at mile 22 to prevent salt water intrusion in the adjacent lakes from high storm tides. The land side levee grade is set at 8 ft throughout. It is considered that major

storms causing tides in excess of 8 ft would be accompanied by winds and rains of such intensity that they would destroy most of the rice crop and pollute the available source of fresh water so that protection of the area from inundation by a higher levee grade, above the maximum storm tide, would not be feasible.

The spoils from channel excavation are all to be deposited in the spoil area along the levee, and it is proposed to deposit these spoils so as to constitute the required levee. It is proposed to limit the height of the spoil dump to about 25 ft above the natural ground. The spoils would be confined by a dragline fill on the canal side with slopes of 1 on 2 and allowed to flow on the river side to slopes of about 1 on 4 to 1 on 6. The spoil embankment for the 9-ft by 100-ft channel under these conditions would have bottom widths varying from 153 ft at mile 21, where the ground elevation is 5 ft, to 363 ft at mile 35, where the ground elevation is about 30 ft. The reach between mile 30 and mile 32.5 includes a short reach through a spur hill where the cut reaches a depth of 55 ft. This section is close to the river channel so that disposal of all the excavated material on the river side would not be practicable and the excess material will be spoiled on the land side of the canal. The spoil from the lock canal would be smaller in quantity and would not require as wide a spoil bank. Under both plans the large quantities of material from the turn-

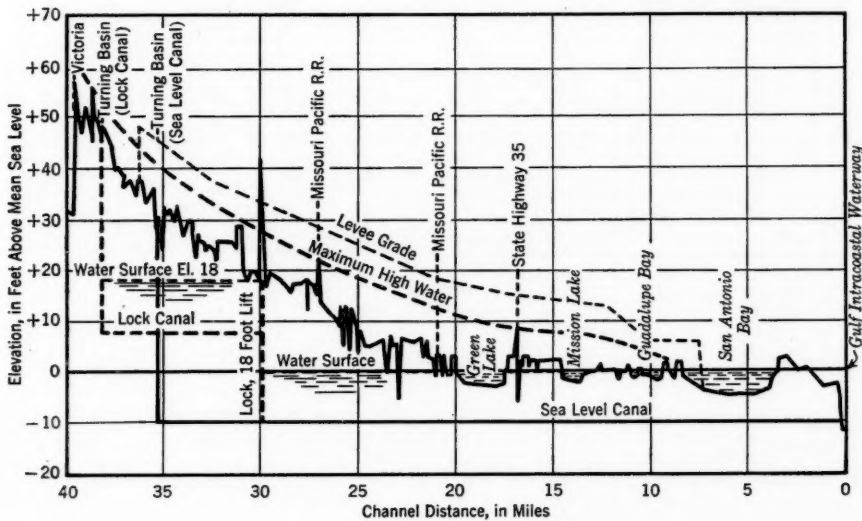


FIG. 2.—NAVIGATION CANAL PROFILES

ing basin would be deposited around the upstream side of the turning basin where the protection levee ties into high ground.

The rights-of-way requirements for the project are dependent on the spoil area required plus the following allowances: A width of 150 ft on the land side of the center line of the channel to allow for erosion and recession of the bank; an additional strip 50 ft wide along the land side of the channel to be controlled by the navigation district; a 40-ft width on the river side to provide

for future widening and deepening of the channel; a 100-ft berm from the future top of the bank to the toe of the slope of the levee or spoil embankment; and a width of 250 ft on the river side of the spoil dump to afford spoil-disposal area for future enlargement and maintenance of the channel and to provide for a large drainage ditch along the river side of the area. The total width of rights of way required for the project, in the reach above mile 22, varies from about 700 ft to 1,000 ft. Typical cross sections showing the several width requirements are depicted in Fig. 3(a).

The parallel levees across Green Lake (Fig. 3(b)) require more material than would be removed from the net channel section, largely because the bed of Green Lake is from 1 ft to 2 ft below mean sea level and because of the flat levee slopes in this reach. The boring samples from the bed of Green Lake show that the subsurface materials are clays and sandy clays, and no difficulty

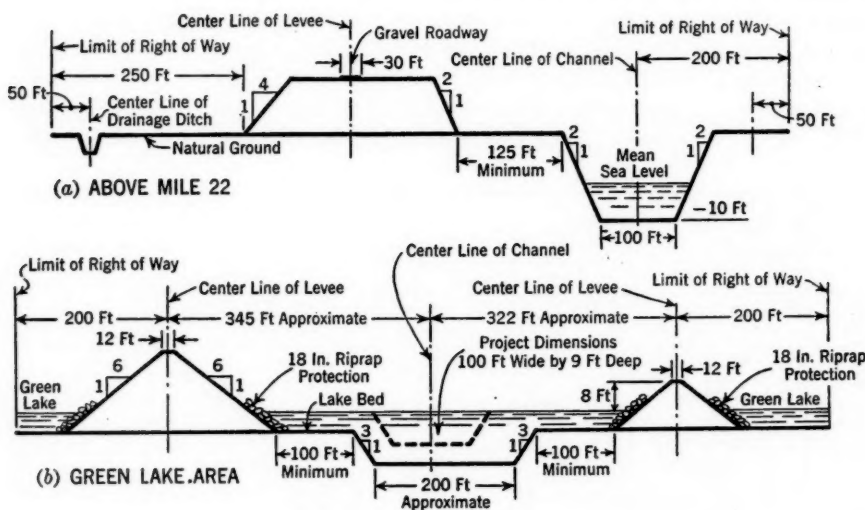


FIG. 3.—TYPICAL CROSS SECTION

is expected in using these materials for constructing levees across the lake. A riprap blanket protection is considered desirable over the parts of these levees exposed to wave action in the lake, and boat wash in the canal, to prevent excessive erosion of the levees.

#### INTERIOR DRAINAGE

The river side protection levee would intercept a drainage area of 73 sq miles for the sea-level canal and 86 sq miles for the lock canal. The natural drainage in this area is by a number of short streams flowing from the adjacent high ground. Above mile 30, the natural drainage is across part of the flood plain to a stream parallel to the river which collects the drainage and carries it to the Guadalupe River. In this reach the channel and levee will be generally along the land side of the drainage stream and will intercept the lateral

drainage. Between mile 30 and Green Lake, another flood plain drainage stream is intercepted by the channel and levee. All of these intercepted lateral drains would discharge directly into the channel. In the design of drainage facilities, each lateral drain was considered separately and methods were determined to discharge the drainage of the twenty-five-year frequency into the channel without erosion of the bank. Either drop-inlet structures or a paved open ditch extending down the bank of the channel is provided. Between the Green Lake area and the Mission Lake area, conduits through the land side levee into the canal would afford the necessary drainage facilities. These structures are designed to carry the estimated runoff of a storm with a frequency of about once in ten years.

Design of the by-pass facilities for the discharge of floodwaters past the lock structure in the canal required a determination of the design flood discharge. The drainage area above the lock structure and within the levee would be about 27 sq miles. A standard project storm is considered to be equal to the maximum observed rainfall in the vicinity of Victoria, which is in close agreement with 50% of the maximum possible precipitation for this drainage area.

The selected standard project storm rainfall is 16 in. in 24 hr and the rainfall distribution is based on the maximum 24-hr precipitation at Cuero, Tex., experienced during the storm of June 28-30, 1940. Infiltration is taken as 1 in. for the first hour and 0.1 in. per hr thereafter. Watershed coefficients of  $C_1 = 3.00$  and  $640 C_p = 300$  were used. The flood hydrograph was determined by developing a synthetic unit hydrograph according to the Snyder<sup>2</sup> method. The peak discharge at the lock site is estimated at 10,300 cu ft per sec. and the lock by-pass structure was designed for this capacity.

A study was made of the possible occurrence of stages and velocities in the navigation channel from run-off from the interior drainage area. The study, based on the Lowry<sup>3</sup> method of computing rainfall frequencies, gave the frequencies of velocities, stages, and discharges shown in Table 2. These data are for mile 22, at the upper end of the parallel levees, and at mile 12 near the lower end of the levee system.

TABLE 2.—DISCHARGE, STAGE, AND VELOCITY FREQUENCIES IN THE NAVIGATION CHANNEL

Frequencies, in years	Estimated discharge (cu ft per sec)	AT MILE 12		AT MILE 22	
		Stage <sup>a</sup>	Velocity <sup>b</sup>	Stage <sup>a</sup>	Velocity <sup>b</sup>
10	5,500	2.6	2.7	4.2	2.3
25	7,200	3.8	3.1	5.8	2.6
50	9,200	5.1	3.6	7.4	2.9
100	11,500	6.4	3.9	9.0	3.0
140	12,800	7.1	4.1	10.0	3.1

<sup>a</sup> In feet above mean sea level. <sup>b</sup> In miles per hour.

#### FRESH WATER SIPHONS

Locating the channel across Green Lake posed the problem of maintaining storage capacity of the entire lake for water supply as desired by the owners.

<sup>2</sup> "Synthetic Unit Graphs," by Franklin F. Snyder, *Transactions Am. Geophysical Union*, Part 1, 1938, p. 447.

<sup>3</sup> "Excessive Rainfall in Texas," by Robert L. Lowry, Jr., *Bulletin No. 25*, State of Texas Reclamation Dept., November, 1934.

A siphon under the canal is proposed to connect the two parts of the lake. This siphon would serve to equalize the water storage in Green Lake and permit the use of all storage in the lake for fresh water supply. The owners of Green Lake have filed a presentation with the Texas State Board of Water Engineers to consider the diversion of 20,000 acre-ft of water per annum from the Guadalupe River into Green Lake. The capacity of a siphon to meet these requirements is 525 cu ft per sec at a head differential of 1 ft. Three 8-ft-high by 6-ft-wide box culverts are required.

A siphon under the canal at the head of Mission Lake is required to provide for the water supply of the rice irrigation system. At present, this company obtains water by two methods: (a) By diversion from the river through Mission Lake and a natural bayou to the pumping station and (b) by diversion from the Guadalupe River at River Mile 10.4, through ditches and natural bayous to the pumping station, where it is lifted to high ground for gravity delivery to the rice fields. The navigation channel crosses both delivery routes and provision must be made for their replacement as an item of rights of way for the channel. A siphon under the canal at the upper end of Mission Lake is proposed. A new delivery canal would be dredged along the river side of the levee to connect with the existing delivery canal. The intake structure of the siphon is provided with two gates so that water can be obtained from Mission Lake or from the Guadalupe River by the delivery canal. The siphon is designed to provide for the existing and proposed increased requirements of water for rice irrigation, which total 600 cu ft per sec. This is provided by three 8-ft-high by 6-ft-wide box culverts. The siphons at Green Lake and Mission Lake will be placed with the top of the box at an elevation of 21 ft below mean sea level for a length of 200 ft under the canal and thence upward to the outer levee toes, giving an over-all length of 850 ft for the Green Lake siphon and 740 ft for the Mission Lake siphon. The inverts of the siphons are set at 2 ft below mean sea level. The intake and discharge ends of the siphons are designed so that stop logs can be placed to close the ends and so that the conduits can be dewatered for cleaning and repairs.

#### LOCK CANAL STRUCTURES

The requirements of a lock canal would be the same as for the sea-level canal up to the lock at mile 29.6, at which point a lock would afford a lift of 18 ft above mean sea level. Above the lock, the bottom of the canal would be at elevation 9 ft above mean sea level. At the upper end of the lock canal, an intake with a capacity of 200 cu ft per sec at a head of 12 ft would be provided for supplying water to the canal from the Guadalupe River. The intake would consist of an open canal about 5,000 ft long with a 4-ft gate-controlled conduit under the levee. A diversion dam would be required in the Guadalupe River to direct flows into the intake canal. A concrete ogee dam is proposed, with a length of 140 ft and crest elevation of 30 ft. The bottom of the river channel at the dam site is at an elevation of 22 ft. A concrete stilling basin, concrete training walls, riprap, and steel-sheet piling protective features are provided. The structure would be founded on steel bearing piles.

The lock chamber would be 75 ft by 400 ft long with the sill at an elevation of 14 ft below mean sea level. Studies have been made of four different plans for details of the lock structure. These plans differed as to the type of gate and as to the provision for the discharge of flood waters from the local drainage area above the dam.

*Plan 1.*—A masonry lock structure was proposed, with a miter gate at the downstream end and a vertical slide gate at the upstream end. There would be a by-pass structure adjacent to the right lock wall with a side gate for the regulation of the upper pool and for the discharge of minor floods; major floods would be discharged through the lock chamber. The upper slide gate could be used in the lock-filling operations.

*Plan 2.*—As in Plan 1, this proposal was for a masonry lock structure with a miter gate at the downstream end. A tainter gate with capacity sufficient to discharge all floods is provided in the by-pass structure, and a miter gate is provided for the upstream lock gate. The upper pool would be regulated and controlled by the by-pass gate.

*Plan 3.*—Likewise, similar to Plan 1, a masonry lock structure was proposed, with a miter gate at the downstream end and a vertical slide gate at the upstream end. In this plan, a by-pass culvert was provided around the upper and lower gates for filling and emptying the lock, and the lock-chamber walls between the gate abutments were to be of steel-sheet piling.

*Plan 4.*—This proposal was exactly the same as Plan 1 except that it would have a lift 3 ft greater to reduce the excavation required above the lock.

Foundation explorations in the lock area indicated the necessity of pile foundations. The borings revealed a gravel stratum about at the floor level of the lock, which would require a steel-sheet pile cutoff wall beneath the lock structure.

*Relative Costs.*—The several plans were outlined by sketches sufficient to furnish data for estimating comparative costs. Plan 3 was the cheapest of the plans investigated but has an inefficient filling and emptying system and would have a higher maintenance cost. Plans 2 and 4 are of approximately the same cost, which is about \$200,000 more than Plan 1. Plan 1 would cause interruption to traffic during major floods and the upstream sliding gate would be subject to excessive obstruction from silt and debris. The lock details in Plan 2 were considered to be the most desirable for the lock canal and comparative cost estimates were based on that plan.

#### TURNING BASIN AND TERMINAL FACILITIES

Turning basins and terminal facilities must be furnished at Victoria and Seadrift by the local navigation districts under the terms of the authorizing act, and are of interest to the Corps of Engineers to the extent of determining the adequacy of the plans proposed by the local interests. It is considered that the turning basin should be at least 400 ft wide and that the Victoria basin should be an off-channel basin so that it will permit upstream extension of the channel. Preliminary designs for this turning basin indicated a basin

400 ft wide, at the project depth of — 10 ft, and about 1,000 ft long, extending at an angle upstream from the channel. The plans provided for future enlargement of the harbor facilities by an extension of the basin and by the construction of a second basin. Designs for wharves and docks on the turning basin and for cargo-handling facilities will be made by engineers employed by the navigation district.

#### BRIDGES AND PIPE LINES

The channel will be crossed by two railroad bridges and one highway bridge and by ten oil and gas pipe lines. The cost of the necessary alterations to these structures must be borne by the local interests. It is proposed that movable bridges be provided with unlimited vertical clearance and 125-ft horizontal clearance between fenders, and that pipe lines be placed at a minimum depth of 21 ft below mean sea level for a width of 125 ft under the channel.

#### WATER SUPPLY FOR THE LOCK CANAL

The question of the adequacy of the water supply in the Guadalupe River for a lock canal required restudy because, in the interval since the project report investigations, an extensive use of the waters of the river had developed. A rice irrigation development in the vicinity of Seadrift obtained its water supply from the Guadalupe. The irrigation company has appropriations of water from the Guadalupe River for a total of 572 cu ft per sec for irrigation. The appropriations are for a total of 55,617 acre-ft of water to irrigate 27,559 acres annually with a maximum rate of withdrawal of 572 cu ft per sec. The installed capacity at the company's pumping plant is 340 cu ft per sec. The method of operation is to pump water from Mission Bay until the bay becomes salty, and then water is drawn from the river intakes. The pumps generally are operated at full capacity for about half of the time during the irrigating season, from April through September.

A second water use is for an industrial development below Victoria. The industry has appropriations for 198,000 acre-ft annually with a maximum rate of withdrawal from the river of 300 cu ft per sec. The pumping plant, with an installed capacity of 45 cu ft per sec is located opposite channel mile 31. Delivery pipes extend across the narrow flood plain at this point to a canal on high ground which carries the water to the plant. Of the total appropriations for industrial use, only 33,000 acre-ft per yr or 45 cu ft per sec is consumed and the remainder is returned to the river uncontaminated.

The consumptive appropriations of water from the Guadalupe River below Victoria total 617 cu ft per sec. In addition, two certified filings have been made with the Texas Board of Water Engineers for (a) appropriations of 20,000 acre-ft annually (approximately 170 cu ft per sec, maximum rate), and (b) water to irrigate 100,000 acres of additional land (approximately 850 cu ft per sec, maximum rate).

The water required for the operation of the navigation lock is estimated at 190 cu ft per sec. This is based on twenty lockages per day with 40% alternation; that is, lockages succeeded by lockages in the opposite direction 40% of the time. The number of twenty lockages per day is based on full develop-

ment of the estimated prospective commerce of 1,600,000 tons annually, with allowance for the lockage of single commercial and pleasure boats. The maximum possible number of lockages based on a half hour for a lockage would be forty eight per day. Allowance is made in estimating the water required for leakage through the gates and valves, seepage, evaporation, and for the excess displacement of inbound commerce. Seepage losses from the canal above the lock might be quite large, even after the provision of cutoff walls through the gravel deposits. The estimated water required for the operation of the lock is as follows:

Purpose	Demand (cu ft per sec)
Lockage.....	112.0
Excess inbound commerce displacement.....	1.3
Leakage at lock gates and valves.....	25.0
Leakage at by-pass gate.....	20.0
Seepage.....	30.0
Evaporation.....	1.9
Total.....	190.2

The total estimated consumptive water demand on the lower Guadalupe and San Antonio rivers, including the navigation requirements and the present appropriations of water for irrigation and industrial use, amounts to 807 cu ft per sec divided as follows:

Purpose	Demand (cu ft per sec)
Irrigation demand.....	572
Industrial use.....	45
Navigation requirement.....	190
Total.....	807

#### WATER SUPPLY

In order to determine the water supply available to meet this demand, a study was made of the records of flow on the Guadalupe and San Antonio rivers. The records at Victoria, mile 51, on the Guadalupe River, are available from 1904 to 1949; and records at Goliad, Tex., mile 66.5 on the San Antonio River, are available from 1924 to 1928 and from 1939 to 1949. Flow-duration curves were compiled from these records for the individual and coincident combined flow of both streams for the six-month irrigation season. The curves for the Guadalupe River at Victoria and the combined curves for the Guadalupe River at Victoria and the San Antonio River at Goliad are shown in Fig. 4.

The line of the maximum demand of 807 cu ft per sec is shown on the graph. It will be noted that for 19% of the time during the six months of the irrigation season (April to September) the natural water supply in the Guadalupe and San Antonio rivers would be insufficient to meet the total demand for agricultural, industrial, and navigational purposes. There would be a deficiency of water on an average of forty-six days annually.

The authorized federal project for the Canyon Reservoir on the upper Guadalupe River would regulate the flow at the dam site to a minimum of about 165 cu ft per sec. If this flow were available on the Guadalupe River below Victoria, the period of insufficient water supply would be reduced to about 10% of the six-month irrigation system, or about eighteen days annually.

The natural water supply would be sufficient for present demand if a method could be devised to utilize the water for the operation of the lock and then make it available for irrigation. The difficulty would be to deliver the water to the irrigation pumps uncontaminated by salt water or other pollution. The navigation canal below the lock would be at sea level and salt water intrusion in the canal from the Intracoastal Waterway would be a certainty, especially during periods of low flow in the rivers when all available water would be

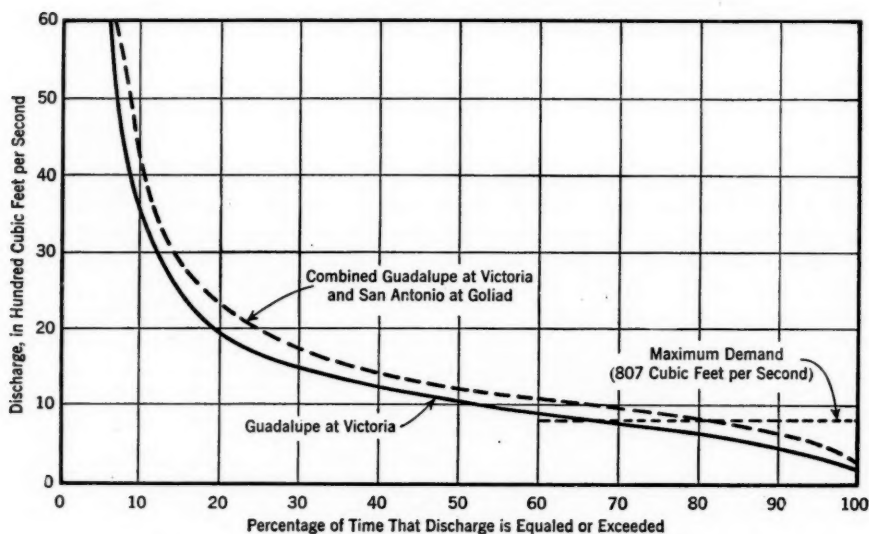


FIG. 4.—FLOW-DURATION CURVES (FOR THE IRRIGATION SEASON ONLY—  
APRIL TO SEPTEMBER, 1924 TO 1928 AND 1939 TO 1949)

needed to meet the demand. A plan that would insure delivery of fresh water from the navigation canal to the irrigation pumps could not be devised other than a plan that required an additional lock and that would increase the cost of the project.

The water supply in the Guadalupe River for operation of a navigation lock under existing conditions would be inadequate during a considerable part of the irrigation season, because of the demand for irrigation and industrial use. The expressed federal policy is to recognize the rights of local interests in water utilization and control. Therefore, operation of the lock canal would be jeopardized during periods of low flow under existing conditions. Further development of uses of water on the rivers would aggravate this situation. Canyon Reservoir, when completed, will appreciably increase the low flow on the lower river and if this flow were available for appropriation exclusively for

operation of the navigation project by the federal government, it would be sufficient to insure continuous operation as required to accommodate navigation. The authorization for Canyon Reservoir states that the storage is for development of hydroelectric power and for navigation. However, there is no assignment of specific quantities of water to navigation, and it is doubtful if, after release of water in the generation of electric power, it could be claimed for navigation on the lower river. An additional reservoir on the Guadalupe River has been found to be economically feasible and has been recommended for construction, but this project has not been authorized by Congress. This reservoir would not afford a regulated water supply for operation of the navigation project below Victoria.

#### COMPARISON OF THE TWO PLANS

The total estimated quantities of excavation for the two projects, including the excavation in the turning basins at Seadrift and Victoria, are as follows:

Canal	Excavation (cu yd)
Lock canal.....	19,600,000
Sea-level canal.....	22,000,000
Difference.....	2,400,000

The first cost of the two plans for a navigation channel were estimated for comparison of the plans. The estimated first cost of the lock canal is \$12,500,000 and of the sea-level canal is \$9,000,000, which gives a saving of \$3,500,000 in favor of the sea-level canal. The annual costs of the sea-level canal would be considerably less than for the lock canal in the reduced interest and amortization on the first cost, and because of the elimination of the maintenance and operation costs of the lock, intake structure, and diversion dam.

An analysis was made of the effect of the change in location of the turning basin on the estimated benefits from saving in transportation cost to the prospective commerce on the channel. The effect is to reduce the length of barge haul and increase the rail, truck, or pipe line haul in the joint movement of commodities. The net result was to reduce the benefits of the project but the difference was not sufficient to affect the favorable ratio of benefits to costs.

In view of the reduced first cost and annual charges, and because of the probable inadequacy of the water supply for operation of the navigation lock, the sea-level canal was considered to be the more feasible project for construction. The adoption of the sea-level canal also would be in the interest of expediting construction of the channel since it would not require the use of any appreciable quantities of scarce construction materials.

#### ACKNOWLEDGEMENTS

The conclusions in this paper are those of the writer and are based on studies prepared by the personnel of the Galveston District, Corps of Engineers.

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